Bell Ringer: The Spring-Mass System – ID: 13622

Time required
15 minutes

Topic: Oscillations and Waves

- *Explore the motion of a mass oscillating on a spring.*
- *Determine the relationships between the force, displacement, and spring constant of a spring-mass system.*

Activity Overview

In this activity, students will observe a simulation of an object oscillating on a spring. Then, students will plot the force of the spring as a function of the displacement to determine the spring constant of the spring.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Data & Statistics, Notes, Graphs & Geometry, Lists & Spreadsheet

Teacher Preparation

Before carrying out this activity, review with students Hooke's law and the properties of systems in simple harmonic motion.

- *The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on page 5 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains sample responses to the questions posed in the student .tns file.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter "13622" in the search box.***
- *This activity is related to activity 10541: Up and Down: Vertical Oscillations. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 10541 at education.ti.com/exchange.*

Classroom Management

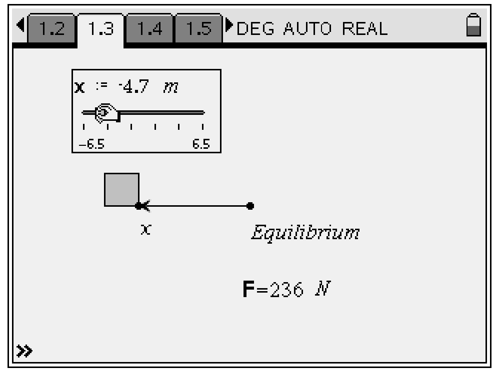
- *This activity is designed to be **teacher-led**, with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *If you wish, you may modify this document for use as a student instruction sheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the main questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

The following questions will guide student exploration during this activity:

- What is simple harmonic motion?
- What is Hooke's law?

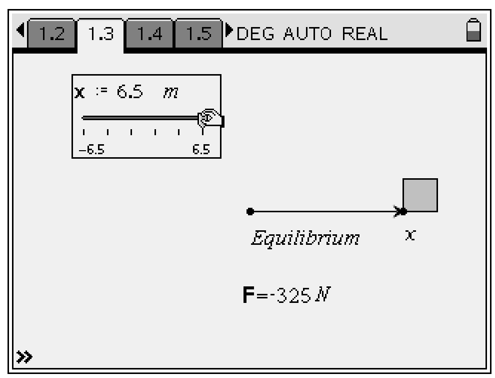
In this activity, students will observe how the spring force on an object is related to the displacement of the object in a spring-mass system. Then, students will plot the force versus displacement of the spring-mass system to determine the spring constant of the spring.

Step 1: Students should open the file **PhysBR_week20_springmass.tns** and read the first two pages. Page 1.3 shows a simulation of a box attached to a light spring on a horizontal surface. The spring-mass system oscillates about an equilibrium point. The force of the spring on the box is given by *F*. The displacement of the box from equilibrium is given by *x*. Students can vary the displacement of the box by moving the slider from –6.5 to 6.5 m. (To use the slider, students should use the NavPad to move the cursor to the slider value located below the variable. They can press to select the slider, and then use the NavPad to drag it to change the values. Alternatively, students can use the NavPad to scroll over the text value of the variable. Students should press twice to delete the value, and then type a new value.) Students should observe how the force on the box changes as the displacement changes. Then, they should answer question 1.

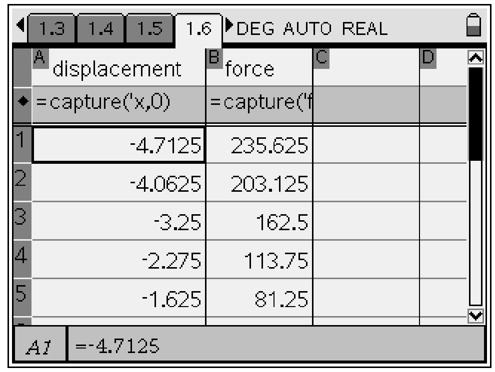


Q1. What do you notice about the sign of the displacement of the object and the sign of the force on the object? Why do you think this is the case?

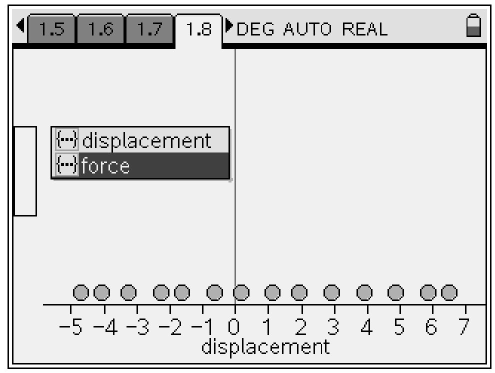
A. *The sign of the displacement is opposite the sign of the force on the object, which is the case for all objects in simple harmonic motion. This is because the spring exerts a restorative force on the object that points in the direction of the equilibrium point. When the object is displaced from equilibrium, the spring exerts a force on the object that opposes this motion.*

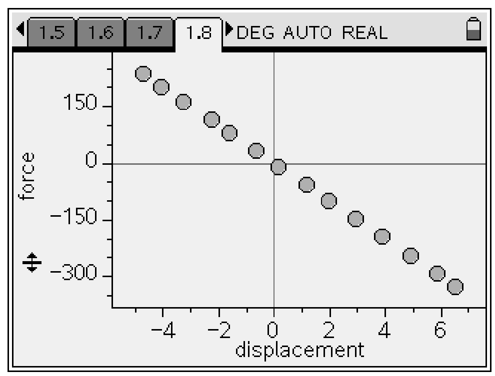


Step 2: Next, students should read page 1.5 and then move back to page 1.3 to capture data points from the spring-mass simulation. Students should press ctrl . to capture a single data point. Students can vary the slider value and then repeat this process until numerous data points have been collected. These data are automatically added to the spreadsheet on page 1.6.

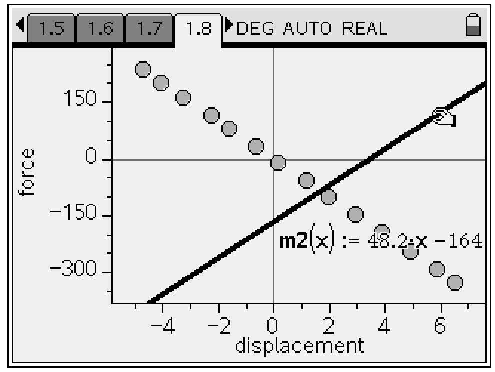


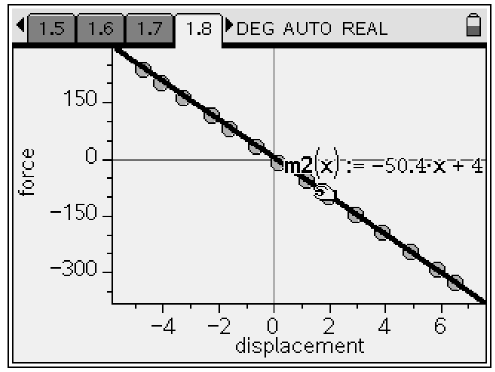
Step 3: Students should read page 1.7 and then move to the *Data & Statistics* page on 1.8. Students should select the appropriate series from the *x* and *y* axes to plot a graph of the force of the spring versus the displacement of the object. (To make the plot, they should use the NavPad to move the cursor to the *x*-axis. They should click once. A list of possible variables should pop up. They should use the NavPad to select **displacement** and then click once. They should then move the cursor to the *y*-axis, click, and choose **force** from the menu. Once both variables have been selected, the graph should appear.)





Step 4: Next, students should fit a line to the data using the **Movable Line** tool (**Menu > Analyze > Add Movable Line**). To adjust the movable line, students should use the NavPad to move the cursor to a location on the movable line. The cursor will turn into either a four-corner arrow or a circular arrow. To grab the line, students should press and hold (click) until the cursor changes to a closed hand. They can then use the NavPad to drag the line. They can press (esc) to release the line. To change the angle of the line, they should grab the line from a point at which the circular arrow is visible. To change the position of the line, they should grab the line from a point at which the four-corner arrow is visible. The equation for the line will be displayed on the screen. Once students have plotted the line, they should answer questions 2–4.





Q2. Write Hooke's law and define each of the variables in the equation.

A. *Hooke's law is F = −kx, where* F *is the force of the spring on the mass,* k *is the spring constant of the spring, and* x *is the displacement of the object from equilibrium.*

Q3. What is the slope of the force versus displacement graph on page 1.7? How does this slope relate to the spring constant?

A. *The slope of the force versus displacement graph gives the ratio* $\frac{F}{x}$*. Based on Hooke's law, this value is equal to* −k*, which is the negative of the value of the spring constant.*

Q4. What is the spring constant of the spring on page 1.2?

A. *The slope of the force versus displacement graph is −50. Because this is equal to* −k*, the value of the spring constant is 50 N/m.*

Q5. According to Hooke's law, what should the *y*-intercept of the line be?

A. *The* y*-intercept should be equal to zero. It is unlikely that students' movable lines will have a zero intercept. Discuss the likely reasons for this. If you wish, have students plot a linear regression (**Menu > Analyze > Regression > Show Linear (mx + b)**) through the points. This line should have a similar slope to the movable line, but should also have a* y*-intercept of zero. Discuss with students the relative accuracy of each line.*

Suggestions for Extension Activities: Have students determine the period, frequency, and angular frequency of the box if it has a mass of 5 kg.

Bell Ringer: The Spring-Mass System – ID: 13622

(Student)TI-Nspire File: *PhysBR_week20_springmass.tns*